SOIL FERTILITY ISSUES

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INTRODUCTION

The Saskatchewan Soil Testing Laboratory is a service organization that provides management and fertility recommendations to the farming community. These recommendations have been developed from scientific research carried out by the University as well as the Provincial and Federal Agriculture Departments. The recommendations represent averages for particular areas (soil zones) in Saskatchewan. Variation from these statistical curves often occurs on an individual field basis. A farmer needs to adjust the average recommendations provided by the soil testing laboratory for the specific conditions found on his farm.

A small program of routine and systematic testing of the soil test recommendations is essential to keep pace with the changes that are constantly occurring in agriculture. Along with changes in cropping strategies come changes in fertilization concepts. Many new fertilization techniques are practiced by Saskatchewan farmers but some are not fully documented. Examples include the use of micronutrients, chloride, and sulphur. The SSTL receives numerous requests from farmers expressing interest in experimenting with these new concepts. A program was established during the growing season of 1990 with the assistance of the Agriculture Development Fund to evaluate several fertility and management practices in farmers' fields.

METHODOLOGY

Thirteen experimental sites were established with ten in the Grey Black soil zone, and one in each of the Brown, Dark Brown, and Thick Black soil zones (Table 1). The fertility issues addressed in this year's projects included the following:

1) Identification of copper deficiency in cereals and canola (9 sites)
2) Identification of boron and sulphur deficiency in wheat and canola (3 sites)
3) Verification of high residual nitrate in a stubble field as indicated by soil test (1 site)
4) Documentation of chloride(potash) response of wheat on a high potassium soil (2 sites)
5) Comparison of lab recommendations for flax on a Grey-Black soil (1 site)

Table 1: Experimental sites included in 1990 demonstrations

Location	Legal Location	Soil Zone	Type of Test	Crop
1. Spiritwood	SE4-51-11-W3	Grey-Black	Cu	Barley
2. Spiritwood	NE31-50-11-W3	Grey-Black	Cu	Barley
3. Mildred	NE22-50-10-W3	Grey-Black	Cu	Oats
4. Prince Albert	NE4-46-27-W2	Grey-Black	Cu	Wheat
5. Prince Albert	SW4-46-27-W2	Grey-Black	Cu	Canola
6. Weldon	SW35-47-24-W3	Grey-Black	Cu	Wheat
7. Laporte	WH2-25-26-W3	Brown	KCl	Durum
8. Landis	NW31-36-17-W3	Dark Brown	KCl	N/A
9. Shellbrook	NW12-51-3-W3	Grey-Black	Lab comparison	Flax/Barley
10. Hagen	NW12-46A-25-W2	Thick Black	N	Barley
11. Shellbrook	NE7-51-2-W3	Grey-Black	S/Cu/B	Canola
12. Shellbrook	NW32-51-27-W2	Grey-Black	S/Cu/B	Wheat
13. Holbein	SW2-50-2-W3	Grey-Black	S/Cu/B	Canola

Test strips were placed in the cooperator's field to evaluate the fertility practices. The cooperator performed all field operations including the application of the fertilizer treatments. The fertilizer strips were arranged in two blocks with the treatments randomized within each block. In most cases, a local fertilizer dealer provided some fertilizer materials and application equipment. A typical strip was one or two widths of the farmer's seeding and harvesting implements.

A composite soil sample of 12 cores was collected from the 0-6" and 6-12" depths for each of the strips prior to fertilizer application. These samples were air-dried and analyzed for available macronutrients and micronutrients. Available chloride was determined for the Laporte and Landis sites to a depth of 24".

The methods of analysis for assessing available nutrients were the standard procedures accepted by the Saskatchewan Soil Testing Lab. Nitrogen and sulphur were determined by flow injection analysis of 0.001 $CaCl_2$ soil extracts. Phosphorus and potassium were determined by auto analyzer and flame photometry respectively on 0.5 M $NaHC0_3$ soil extracts. The micronutrient cations were determined by inductively coupled plasma spectophotometry (ICP) on 0.005 M DTPA soil extracts. Boron was determined by ICP on 1N NH_4OAc soil extracts. Chloride was determined by auto analyzer on 0.01 M monohydrate $Ca(H_2P0_4)_2$ soil extracts.

The fertilizers were applied to the test strips by several methods. The broadcast copper strips at Spiritwood and Mildred (Sites 1, 2, and 3) were fertilized with copper sulphate by a pneumatic applicator prior to preseeding operations and at Weldon, Shellbrook, and Holbein (Sites 6, 11, 12, and 13) with copper sulphate prior to preseeding operations with a rotary fan broadcast spreader. Boron as sodium tetraborate and sulphur as ammonium sulphate were applied at Shellbrook and Holbein (Sites 11, 12, and 13) with a rotary fan broadcast spreader prior to preseeding operations as well. Copper at Prince Albert (Sites 4 and 5) was applied as a chelate with a backpack hand sprayer. Nitrogen at Hagen (Site 10) was applied as ammonium nitrate with a rotary fan broadcast spreader three weeks after the crop had emerged. Seed placed fertilizer treatments included copper as a copper oxide/sulphate mixture at Spiritwood (Sites 1 and 2) as well as chloride as potash at Laporte (Site 7).

Whole plant tissue samples were collected from each strip at the flagleaf/early boot stage for cereals and at the bud stage for canola. At Site 9, only flax plants were sampled. In each case, approximately 15 plants were composited for the sample.

The nutrient concentration in plant tissue was determined by ICP on nitric-perchloric acid digests. Nitrogen levels were determined by Leco analyzer.

Grain yield was assessed by threshing a measured distance of swath with the cooperating farmer's combine and weighing the grain in a portable weigh wagon. In cases where this was not possible, a pair of two square meter samples were harvested from each of the strips just prior to swathing. Hand harvested grain samples were dried and threshed by a Vogel flail thresher.

RESULTS AND DISCUSSION

Soil test levels

Soil test results for each site are reported in Table 2. The values reported are averages of nutrient levels for the strips at each site. Nitrate - N and sulphate - S are reported for a 12" sampling depth. Phosphorus, potassium, and the micronutrients are reported for a 6" sampling depth. Chloride is reported for a 24" sampling depth.

Several nutrient levels are low at the different sites. Potassium was very low at Sites # 1 and 2. Sulphur was low for cereal production at Site # 3 and for canola production at Sites # 5, 11, and 13. All deficiencies of macronutrients were corrected by application of the appropriate blends for each of the sites concerned. Copper is low at Sites # 1, 2, 4, 5, 6, and 11. Boron was below the critical level for crop production at both Sites # 4 and 5. These two sites also had the highest phosphorus content among the 13 sites. Iron, manganese and zinc were adequate at all of the sites.

Table 2: Soil test levels at the experimental sites (lb/ac)

	NO_3-N	P	K	SO_4-S	Cu	Fe	Mn	Zn	B	Cl
	(12")	(6")	(6")	(12")	(6")	(6")	(6")	(6")	(6")	(12")
1. Spiritwood	31	15	150	48	1.0	45	9.0	3.5	3.0	-
2. Spiritwood	48	25	150	18	0.8	89	15.0	2.7	1.2	-
3. Mildred	41	52	540	13	1.2	63	12.0	5.0	2.1	-
4. Prince Albert	47	51	355	19	0.7	75	17.0	3.2	0.6	-
5. Prince Albert	39	58	370	20	0.5	80	11.0	4.0	0.6	-
6. Weldon	22	21	260	48	1.0	83	8.0	3.0	3.7	-
7. Laporte	39	12	400	48	-	-	-	-	-	88
8. Landis	70	34	680	46	-	-	-	-	-	329
9. Shellbrook	24	42	450	22	1.1	66	15.0	2.3	1.6	-
10. Hagen	81	31	610	34	1.3	137	22.0	5.4	1.1	-
11. Shellbrook	46	20	215	21	0.9	64	12.0	3.8	2.0	-
12. Shellbrook	96	17	290	25	1.4	67	9.0	3.8	5.2	-
13. Holbein	35	19	255	23	1.1	80	5.5	3.7	4.0	-

Plant tissue levels

Average plant tissue concentrations of nutrients for each treatment at the demonstration sites are reported in Table 3. Levels of nitrogen, phosphorus, potassium, sulphur, calcium, magnesium, iron and zinc are adequate for the respective crops at each of the sites.

Soil fertility issues

1. Copper fertility

Six of the nine sites had low soil test copper levels, but only two of these sites had a significant yield response from copper application (barley at site # 2 and wheat at site #4). The summary of the yield results for the nine sites that received copper fertilizer is shown in Table 4. Neither visual differences in growth nor low levels of copper in plant tissue were observed in the barley at Site #2, but head bending was very prominent in the wheat at Site #4 on knolls throughout the field. The deficiency at Site #4 was confirmed by the low copper levels in the wheat plant tissue as well as the 30% yield response to foliar copper application. Copper deficiency in this field was not visually evident at midslope or depression positions in the landscape. The high available phosphorus level in the field may have contributed to the larger yield response of wheat to copper spray in this field. (Touchton et al, 1980). Two other fields (site #6 and #11) showed visual symptoms of copper deficiency in wheat on light textured knoll positions, but the strips of copper were applied to other parts of the field. The head bending indicative of copper deficiency was also evident in a blowdirt ridge along the edge of the field at site #6.

Identification of copper deficiency with plant tissue analysis is complicated by the Piper-Steenbjerg effect. The concentration of copper in whole plant samples frequently increases as the degree of deficiency progresses from marginal to severe (Robson and Reuter, 1981). In addition, differences in copper concentration of the plant tissue between deficient and healthy plants are frequently small (Caldwell, 1971). Levels of 4-5 µg Cu/g plant tissue are associated with mild deficiency. Because of these difficulties, a combination of visual symptoms, plant tissue testing and soil testing is required to confirm copper deficiency. Sampling of the youngest fully expanded leaf of the plant may also help to identify copper

Table 3: Nutrient concentrations of plant tissue samples

	Treatment	N	P	K	S	Ca	Mg	Cu	Fe	Mn	Zn	B
		%	%	%	%	%	%	µg/g	µg/g	µg/g	µg/g	µg/g
1. Spiritwood	Control	4.7	.43	3.8	.33	.81	.32	9	411	28	43	9
	Copper- SP	4.8	.44	3.2	.34	.79	.32	10	528	29	36	11
	Copper-BR/SP	4.7	.45	3.3	.35	.91	.33	11	440	29	35	10
2. Spiritwood	Control	4.5	.39	3.4	.33	.87	.36	8	120	37	29	5
	Copper- SP	4.2	.36	2.9	.33	.87	.37	7	112	37	31	4
	Copper-BR/SP	4.5	.47	3.3	.34	.97	.39	8	150	38	32	6
3. Mildred	Control	4.5	.39	3.4	.33	.87	.36	8	120	37	29	5
	Copper-BR/SP	4.5	.47	3.3	.34	.97	.39	7	112	37	31	4
4. Prince Albert	Deficient	3.9	.67	3.2	.29	.70	.17	5	155	61	28	6
	Adequate	4.8	.50	3.5	.32	.56	.20	10	300	43	37	5
5. Prince Albert	Control	4.7	.76	6.4	.75	1.90	.35	7	171	55	40	26
6. Weldon	Control	3.6	.49	3.5	.31	.40	.22	7	99	23	29	8
	Copper - BR	3.4	.46	3.3	.28	.39	.20	7	91	23	28	7
7. Laporte	Control	4.4	.62	3.0	.44	.94	.17	9	380	56	40	10
	Potash - SP	3.9	.49	3.0	.42	.74	.16	8	317	58	26	11
9. Shellbrook	SSTL	4.3	.46	3.1	.37	1.37	.43	7	101	76	29	25
	Lab X	4.4	.49	3.1	.36	1.51	.39	8	100	89	25	20
10. Hagen	Rep 1	3.2	.43	3.0	.30	.60	.19	6	123	26	37	7
	Rep 2	2.8	.39	2.9	.29	.53	.18	6	121	20	29	6
	Rep 3	2.5	.37	2.1	.24	.40	.15	10	110	16	45	10
	Rep 4	2.8	.41	3.6	.28	.37	.19	7	103	26	30	7
	Rep 5	3.0	.34	3.3	.28	.40	.20	6	106	20	27	7
	Rep 6	2.8	.39	3.3	.30	.35	.19	7	108	19	23	7
11. Shellbrook	Control	6.4	.71	3.3	.66	2.93	.66	10	626	45	41	34
	Boron	6.1	.65	3.2	.62	2.86	.58	11	602	55	38	34
	Copper	6.4	.67	3.0	.64	3.20	.61	11	658	53	39	32
	Sulphur	6.6	.72	2.9	.70	3.06	.66	10	610	53	44	34
12. Shellbrook	Control	4.3	.37	3.6	.26	.36	.25	7	95	14	24	7
	Boron	4.4	.44	4.1	.30	.45	.28	8	128	16	30	6
	Copper	4.0	.44	4.0	.30	.52	.29	8	138	17	26	6
	Sulphur	4.2	.36	4.1	.28	.37	.27	8	98	17	27	7
13. Holbein	Control	5.7	.83	2.9	.65	2.47	.53	10	177	29	39	27
	Boron	5.6	.79	3.2	.59	2.61	.54	11	215	30	40	35
	Copper	5.9	.91	3.7	.68	2.70	.55	11	206	29	42	25
	Sulphur	6.0	.86	2.8	.71	2.97	.61	11	-	-	43	28

deficiency in plants. Levels of copper less than 2.0 µg Cu/g of plant tissue in these samples are considered deficient (Gartrell and Brennan, 1979).

The level of copper was low for wheat in plants that showed visual growth symptoms of copper deficiency at Site #4. Areas of this field with normal growth had adequate levels of copper in the plant tissue. The nearby canola field had adequate levels of copper in plant tissue even though the soil test for available copper was lower. No visual evidence of poor growth was evident in this field of canola although the soil test indicated that site #5 had a lower level of available copper in the soil. Wheat is considered a better indicator of marginal copper deficiency than canola because of the characteristic visual symptoms of copper deficiency. Pockets of marginal or immanent copper deficiency are widespread across portions of the Black, Grey-Black, and Grey soil zones in the province. Farmers should be aware of the visual symptoms of copper deficiency in wheat and types of soils that are susceptible to the deficiency. The most obvious symptoms associated with this nutritional problem are head bending, blackening of the stem just below the head and "bran-frosted" low bushel weighted grain. Light textured and peaty soils are most susceptible to copper deficiency. Greater incidence of copper deficiency would be observed if weather conditions were less favourable for plant growth (Reith, 1968).

Table 4: Summary of Copper Fertilizer Experiments

Location	Crop				Yield response (%)
		Control	Cu - SP	Cu - BR/SP	
1. Spiritwood	Barley	4530	4550	4600	None
2. Spiritwood	Barley	3510	3830	3950	12.5
		Control	Cu - BR		
3. Mildred	Oats	4880	4760		None
		Control	Cu - Spray		
4. Prince Albert	Wheat	2600	3390		30.4
5. Prince Albert	Canola	1050	960		None
		Control	Cu - BR		
6. Weldon	Wheat	3930	3900		None
		Control	Cu - BR		
11. Shellbrook	Canola	1560	1490		None
12. Shellbrook	Wheat	4760	4730		None
13. Holbein	Canola	2070	2130		None

Copper Treatments: Cu - BR ($CuS0_4$ broadcast at 5 lb Cu/ac)
Cu - SP (Cu oxide/sulphate mixture seed placed at 1 lb Cu/ac
Cu - Spray (Cu chelate applied to foliage at flagleaf at 0.2 lb/ac)

The best means of correcting copper deficiency is broadcasting 3-5 lb Cu per acre. This rate should correct the deficiency for more than five years on sandy soils. Fine granulated fertilizer sources are usually more effective than larger granuled sources. Copper is not mobile in the soil, but incorporation will distribute the fertilizer throughout the soil over time. A lag in response to the fertilizer application may be observed for less soluble or larger granulated fertilizer sources. The results for the trials at Site #1 and #2, however, indicate that seed placed copper at 1 lb per acre may be an effective method of correcting the deficiency. Further work is required to verify this practice.

2. Boron and sulphur fertility

Portions of north central Saskatchewan have been experiencing lower than expected wheat and canola yields over the past few years. The region avoided the harsh drought conditions but was still receiving yields lower than the local farmers' expectations. Several possible explanations were identified: 1) excessive N:S ratio in the soil inducing a sulphur deficiency, 2) low available soil boron levels (for canola), 3) low available soil copper levels and 4) excessive heat / drought. The trials established in the Shellbrook region assessed which of these possible problems were responsible for the low yields.

The yield results for these trials are summarized in Table 5. No response in yield was observed from the application of boron to wheat or canola. Soil test levels of boron were adequate in all three fields. A visual effect of boron application was observed at Site #13. The canola plants in the boron-treated strips at Holbein were crisper (had higher turgor pressure) than the canola in the other strips at the time of tissue sampling. In spite of this effect, no differences in flowering of the canola were observed. Tissue levels of boron in the boron-treated strip were in the adequate range compared to the other three treatments which contained marginal levels of boron in the canola tissue (Table 3). The levels of boron in the canola and wheat fields at Shellbrook (Site #11 and 12) were adequate.

Table 5: Yield Summary of Boron and Sulphur Experiments

Location	Crop				Yield response (%)
		Control	Sulphur	Boron	
11. Shellbrook	Canola	1560	1590	1520	None
12. Shellbrook	Wheat	4760	4950	4860	None
13. Holbein	Canola	2070	2140	2020	None

Treatments: Sulphur: 10 lb S/ac broadcast as 20-0-0-24
Boron: 1.5 lb B/ac broadcast as sodium tetraborate on canola
0.5 lb B/ac broadcast as sodium tetraborate on wheat

The soil test level for boron was low at Site #4 and 5. Canola tissue levels of boron were marginal according to the interpretive criteria of the lab, but the plant tissue levels in wheat at Site #4 were adequate. Canola is more sensitive to boron deficiency than cereals, however, the critical concentration of boron in plant tissue for canola and the critical level of boron in soil may be too high for crops that are commonly grown in Saskatchewan. Alfalfa may be a better indicator of a soil's boron fertility than the common grain crops.

The increase in yield observed from the application of sulphur to these strips was not significant, but occurred at all three locations. This trend could be due to a high N:S ratio in the canola plant from an excessive N:S ratio in the plant tissue or to extra nitrogen in the ammonium sulphate which was utilized by the crop because of excellent moisture conditions. The region enjoyed good timing of rainfall during 1990 and the trend towards a higher yield in the sulphur strips could be a response to the extra nitrogen. This factor is especially relevant for the wheat crop. The total N: total S ratio in the canola for Site #11 and #13 varied between 8.5 and 10.0. Maynard (1983) found that the optimum ratio of total N:total S in canola tissue at the 2.2 to 2.4 rosette growth stage varies from 5 to 7. Karamanos (1988) found that maximum seed yields of canola were associated with N:S ratios of 6 to 8 in plant tissue samples at flowering. Based on these two studies, it is likely that high nitrogen or low sulphur levels in the plant is contributing to the reduced yields of canola at sites #11 and #13.

3. Chloride fertility

Of the two sites selected for testing with potassium chloride, chloride strips were established only at Laporte (Site #7). The farmer at Landis (Site #8) wanted to seed mustard and did not realize that the chloride yield response has only been observed for cereals. This field was located only 2 miles from the Palo salt mine. The level of chloride in the various soil samples collected from his field varied widely, but was correlated directly with the salinity level (Figure 1). Van Beek et al. (1975) found that chloride represented a constant percentage of the total salts present in the soil associations found in the vicinity of potash mines in Saskatchewan. Because of this relationship, responses to chloride should not be expected on salt-affected soils.

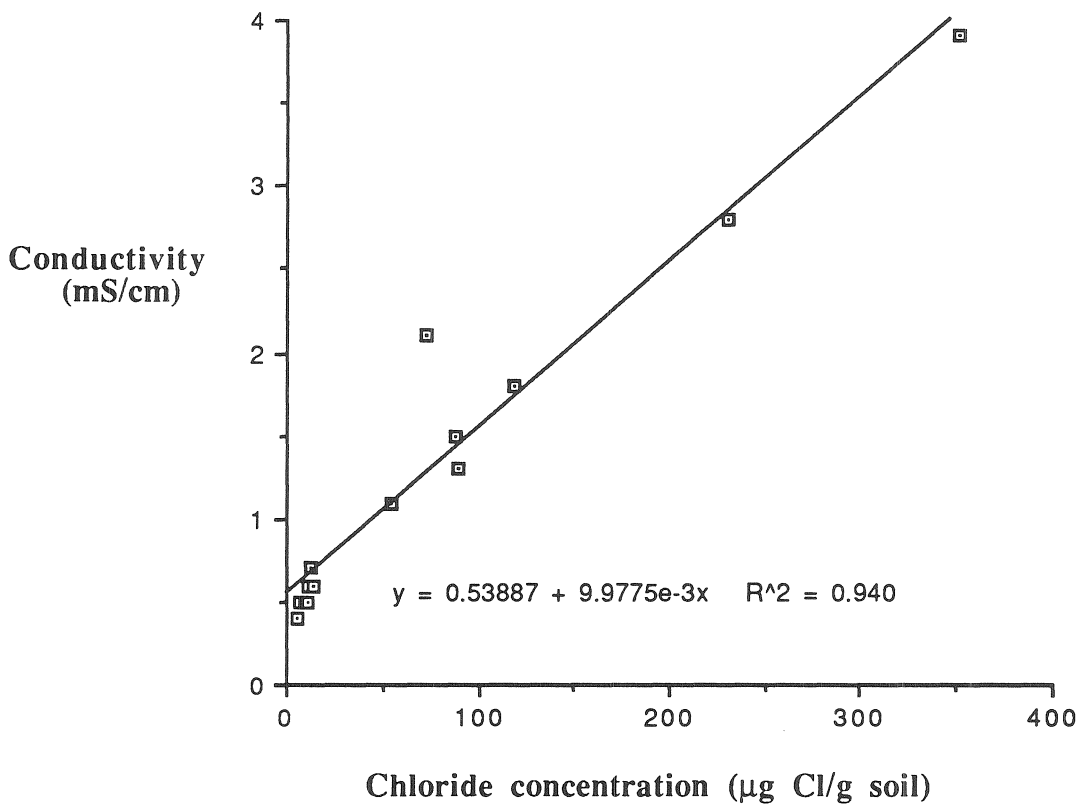

Figure 1: The relationship of chloride level in the soil to conductivity at Site #8.

The yield results for the potassium chloride experiment at Laporte are reported in Table #6. The field was affected by severe drought in 1990. No response of durum wheat yield or plant potassium concentration to application of 25 lb potash per acre was observed in the concentration of potassium in the plant tissue (Table 6) nor in the grain yield.

Table 6: Yield Summary of Potassium Chloride Experiment

Location	Crop	Control	25 lb Potash	Yield response (%)
7. Laporte	Durum	1810	1800	None

4. Nitrogen fertility

A flax stubble field at Hagen was sampled by a fertilizer dealer during the fall of 1989. Because the field had high residual nitrogen levels according to the soil test and received a zero nitrogen fertilizer recommendation, a second set of samples was taken which verified the original test results. Nitrogen strips were established at rates of 0, 25, and 50 lb N/ac to determine whether the zero nitrogen recommendation was warranted in this field. Although the treatment identity for the six strips is unknown, the nitrogen level in the barley plant tissue for all six strips was adequate and the difference in yield between the strips was less than 450 kg/ha (Table 7). Assuming that the lowest and highest yields were associated with application of 0 and 50 kg N/ha and a nitrogen price of 20¢ per lb of N, the return to investment would become economical at a barley price of $1.70 per bushel. The response in yield was small, however, relative to normal yield responses to nitrogen fertilization on stubble.

Table 7: Nitrogen content in plant tissue and grain yield of barley at Site #10

Strip I.D.	%N in plant tissue	Grain Yield (kg/ha)
Rep 1	3.2	2590
Rep 2	2.8	2860
Rep 3	2.5	2710
Rep 4	2.8	2560
Rep 5	3.0	3020
Rep 6	2.8	2800

5. Lab comparison

The comparison of soil test results for Lab X and the Saskatchewan Soil Testing Laboratory are reported in Table 8. The agreement of the results between the two labs is excellent, but the recommendations vary especially for micronutrients. The plant tissue levels of the flax for the two fertilizer recommendations indicate that plant tissue levels of the applied micronutrients were adequate in both treatments. Boron and zinc tissue levels of the flax responded to the application of micronutrients. Although the proportion of volunteer barley varied throughout the field, no response in yield was observed from the extra investment in micronutrients on this field.

Table 8: Comparison of the soil test results and fertilizer recommendations of Lab X and the Saskatchewan Soil Testing Lab (SSTL) at Site #9.

Lab X Soil Test Data:

	pH	Cond (mS/cm)	N03-N (lb/ac)	P (lb/ac)	K (lb/ac)	S04-S (lb/ac)
0-6"	7.6	0.2	14	42	502	10

	Cu (lb/ac)	Fe (lb/ac)	Zn (lb/ac)	Mn (lb/ac)	B (lb/ac)
0-6"	0.8	57	2.2	9	1.0

SSTL Soil Test Data:

	pH	Cond (mS/cm)	N03-N (lb/ac)	P (lb/ac)	K (lb/ac)	S04-S (lb/ac)
0-6"	7.5	0.2	12	42	450	11
6-12"	7.9	0.3	12	25	240	11

	Cu (lb/ac)	Fe (lb/ac)	Zn (lb/ac)	Mn (lb/ac)	B (lb/ac)
0-6"	1.1	66	2.3	15	1.6

Fertilizer Recommendations (lb/ac):

	N	P205	K20	S
Lab X	80	0	15	15
SSTL	85	15	0	10

	Cu	Mn	Zn	B
Lab X	0.5	1.0	1.5	2.0
SSTL	0	0	0	0

Plant Tissue Analysis:

	N %	P %	K %	S %	Ca %	Mg %	Cu µg/g	Fe µg/g	Mn µg/g	Zn µg/g	B µg/g
Lab X	4.3	0.46	3.1	0.37	1.37	0.43	7	101	76	29	25
SSTL	4.4	0.49	3.1	0.36	1.51	0.39	8	100	89	25	20
Adequate	1.8	0.25	1.5	0.15	0.2	0.2	3.5	20	20	15	5

	Yield kg/ha
Lab X	1880
SSTL	2140

CONCLUSIONS

1. Yield responses to application of copper fertilizers occurred at two of nine sites. Visual symptoms of the deficiency were evident in wheat at three sites on sandy knolls or along blowdirt ridges. Good moisture conditions may have limited the magnitude and occurrence of yield responses.

2. No yield response was observed from the application of boron to canola or wheat. The trend toward yield response from sulphur application in canola may have been due to excessive N:S ratios in the plant.

3. No yield response occurred from the application of 25 lb/ac of potash to the seed of durum wheat.

4. Yield response to the application of extra nitrogen on a field of barley with a zero nitrogen recommendation was small.

5. The recommendation for micronutrient application to flax based on a soil analysis by a out-of-province soil testing facility was not warranted by nutrient levels in the plant tissue of flax. The SSTL did not recommend application of micronutrients to the field based on its soil analysis.

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